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Rocky Mountain Forest and Range Experiment Station

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General Technical Report RM-246

An Ecological Basis for Ecosystem Management

Preface

This report was prepared by the Southwestern Regional Ecosystem Management Study Team composed of management and research biologists. The USDA Forest Service Southwestern Region's Regional Forester, Larry Henson, and the Rocky Mountain Forest and Range Experiment Station Director, Denver Burns, chartered this team to recommend an ecological basis for ecosystem management. This report is not intended to provide details on all aspects of ecosystem management; it simply provides information and makes recommendations for an ecological basis for ecosystem management. The report is not a decision document. It does not allocate resources on public lands nor does it make recommendations to that effect.

The report of this Study Team may be relied upon as input in processes initiated under the National Environmental Policy Act (NEPA), National Forest Management Act (NFMA), Endangered Species Act (ESA), Administrative Procedures Act (APA), and other applicable laws. The information contained in this report is general in nature, rather than site specific. Implementation of ecosystem management and allocation of resources on Forest Service administered lands is the responsibility of the National Forest System in partnership with Forest Service Research and State and Private Forestry. Implementation is done through Forest and project plans that are subject to the NEPA process of disclosing the effects of proposed actions and affording the opportunity for public comment. The Southwestern Region follows a planning process for projects called Integrated Resource Management (IRM).

The opinions expressed by the authors do not necessarily represent the policy or position of the U.S. Department of Agriculture, the Forest Service, The Nature Conservancy, or the Arizona Game and Fish Department.

The Study Team acknowledges the valuable input of more than 50 individuals from various agencies, universities, professional organizations, and other groups who provided thoughtful comments of an earlier draft of this document. Some of their comments are included in Appendix 3.

(Upper left) Road expansion to accommodate increased traffic in forested areas. Photo from Bev Driver.

(Upper right) *Cypripedium calceolus*, a rare species found on the Santa Fe National Forest, New Mexico. Fine-filter analyses help protect uncommon species. Photo by Reggie Fletcher.

(Lower) Small openings in a ponderosa pine forest created by hotspots in a low-intensity fire. Photo by Ron Moody.

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An Ecological Basis for Ecosystem Management

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Contents

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A NEED FOR CHANGE

"When our rifles were empty, the old wolf was down. . . . We reached the old wolf in time to watch a fierce green fire dying in her eyes. I realized then, and have known ever since, that there was something new to me in those eyes — something known only to her and to the mountain. I was young then, and full of trigger-itch; I thought that because fewer wolves meant more deer, that no wolves would mean hunters' paradise. But after seeing the green fire die, I sensed that neither the wolf nor the mountain agreed with such a view."

— Aldo Leopold (1949).

Aldo Leopold recognized the concept and need for ecosystem management decades ago. Deputy Chief James C. Overbay (1992) stated in a landmark Forest Service policy speech that "it is time to embrace the concept of managing ecosystems to sustain both their diversity and productivity and to chart a course for making this concept the foundation for sound multiple-use and sustained yield management." To further emphasize this change, F. Dale Robertson, former Chief of the USDA Forest Service, directed each Regional Forester to develop guidelines for using an ecological approach to manage the National Forests and Grasslands (Robertson 1992). Shortly after his announcement, the Chief stated that "the Forest Service is committed to using an ecological approach in the future management of the National Forests and Grasslands . . . . By ecosystem management, we mean an ecological approach will be used to achieve the multiple use management of our National Forests and Grasslands. It means that we must blend the needs of people and environmental values in such a way that the National Forests and Grasslands represent diverse, healthy, productive and sustainable ecosystems."

Because of these needs and in accord with the Chief's directive, the Southwestern Regional Forester and the Rocky Mountain Forest and Range Experiment Station Director developed a strategy to guide the implementation of ecology-based multiple-use management in the Southwestern Region (Henson and Montrey 1992). The Southwestern Regional Ecosystem Management Study Team (see Appendix 1) was established to assist in this implementation. This report completes the Study Team's charter (see Appendix 2) and represents the Team's consensus regarding an ecological approach for ecosystem management. The Southwestern Region also established two other groups: a Human Dimensions Study Group to examine integration of social and biophysical information into ecosystem management, and an Ecosystem Management Interdisciplinary Team to address the actual implementation of ecosystem management on National Forest lands.

THE HUMAN DIMENSION IN ECOSYSTEM MANAGEMENT

Humans influence and are influenced by ecosystems. Thus, humans are an integral part of today's ecosystems and fully depend on ecosystems for their well-being. Yet as fundamental as this concept is, there is considerable tension regarding the role humans have in ecosystems and the latitude the human race should assume for manipulating ecosystems for its own purposes. Part of this tension comes from mixing short-term and long-term aspects of human/ecosystem interaction. In the short run, ecosystems provide goods and services, including livelihood, for many people. In the long run, ecosystems must persist if they are to provide the same opportunities for later generations. The central goal and

problem of ecosystem management is to balance the short-term demands for products and services with the long-term need for persistence.

Society has become concerned about the human condition and its relationship with ecosystems. We have learned that we cannot have a wise relationship with our environment by looking at it piecemeal or by ignoring the long-term effects of our actions. As a species, we have outdistanced our predators, drastically increased our numbers, and dominated many of our ecosystems, often using highly developed technology. Clearly, a number of global examples exist where ecosystems have been destroyed or severely damaged, leaving behind societies that struggle for subsistence. In the United States, the per capita rate of use of natural resources is one of the highest in the world. While natural resource utilization has benefited the economies of local communities, these benefits are offset by reductions in many important habitats and plant and animal species they support. Furthermore, we often have favored certain wildlife species such as elk and deer without thoroughly understanding the consequences to other species. These losses are a major reason the Forest Service and other important land management agencies, as well as a number of professional and special-interest groups and organizations, are moving purposefully toward a more holistic form of managing ecosystems for long-term sustainability.

The task is daunting, reaching far beyond rates of tree harvest. It includes difficult issues such as air and water pollution and incompatible conterminous land use for which mitigation procedures are difficult at best. In many cases, humans not only depend on ecosystems, they also are the dominant stress to ecosystems. Much of the human stress to ecosystems stems from economic philosophy emphasizing a short-term profit motive and from simple increases in population density, both of which impact resources and seriously challenge the concept of sustainability. When advanced technology is factored in, humans have exhibited great capacity to disrupt ecosystem processes.

Heavily used foot trail resulting in extensive soil erosion and damaged root systems. Photo from Bev Driver.

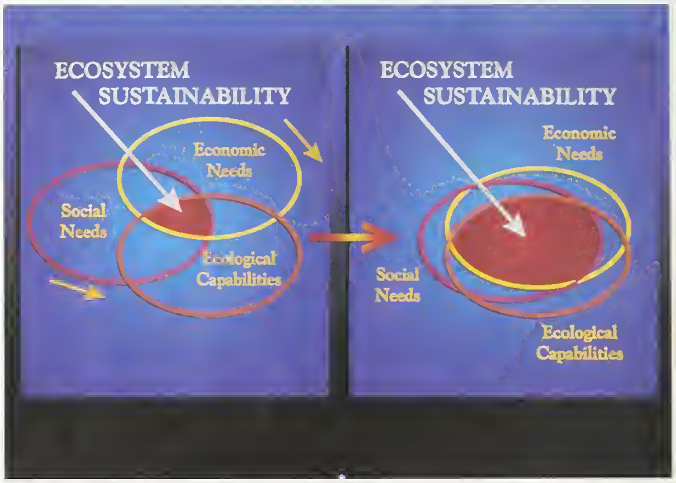


Figure 1. — (Left) Relationship between ecosystem capabilities and social and economic needs; (Right) Relationship between ecosystem capabilities and social and economic needs with greater convergence, resulting in improved ecosystem sustainability. Because the physical and biological capabilities of ecosystems are limited in flexibility, convergence requires shifts in social and economic needs to comply more with ecosystem capabilities.

While our study focuses on ecological characteristics rather than social and economic considerations, clearly the closer that ecological, social, and economic considerations are in agreement, the greater is the likelihood that both ecosystems and society will be sustainable (fig. 1). Much past human impact lies outside the physical and biological capability of sustainable ecosystems. Much of this impact may have resulted from human wants far exceeding needs, and the result has been a significant deterioration in many ecosystems.

Ecosystem management is a logical step in the evolution of society's thinking and understanding about natural resource management. Ecosystem management involves a shift in focus from sustaining production of goods and services to sustaining the viability of ecological, social, and economic systems now and into the future. This is brought about by bringing ecosystem capabilities and social and economic needs into closer alignment (fig. 1 right). But ecosystems function sustainably only when they remain within normal bounds of their physical and biological environment. Thus ecosystem management will be successful only when management decisions reflect understanding and awareness of ecological principles related to sustainability.

It is important to recognize that the human interest is served if long-term ecosystem sustainability is assured, even if this requires altering certain human activities to stay within the physical and biological capabilities of ecosystems. Jack Ward Thomas, current Chief of the USDA Forest Service, stated: "I share a land ethic put forward by an early Forest Service employee named Aldo Leopold, and I quote, 'A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community.' This ethic accepts short-term constraints on human treatment of land so as to ensure long-term preservation of the integrity, stability, and beauty of the biotic community. I believe that human

activity that is consistent with this ethic is properly within the realm of resource management options. Activity which would not be consistent with the long-term preservation of the biotic community should be resisted for all but the most compelling reasons" (Thomas 1994).

Ecosystem management may require new approaches such as less dependence on raw fiber, better utilization of existing natural resources, and reduced human demands. Whether or not society has the capacity or fortitude to sustain ecosystems, efforts toward this goal probably will reduce the magnitude of long-term social problems associated with ecosystem abuse. In a later section (Integrating Ecosystems and Human Needs), we examine how human aspects of human/ecosystem interaction might be addressed.

A way to approach ecosystem management is to identify underlying principles that apply uniformly regardless of the types of ecosystems being considered. The following section addresses principles for managing ecosystem resources.

GUIDING PRINCIPLES

In examining ecological aspects of ecosystem management, the Study Team formulated guiding principles based upon the fundamentals of conservation biology. These principles address portions of the ecosystem management principles outlined at a USDA Forest Service (1992a) workshop in Salt Lake City, Utah. The principles presented here, however, focus primarily on the ecological aspects of ecosystem management and are not intended to address all issues of managing ecosystems at the same level of detail. The guiding principles presented below are very similar to Grumbine's (1992) ecosystem management goals.[3] While not all principles are universally accepted and may be found inadequate in certain cases,[4] the Study Team concluded that the guiding principles outlined below address most of the biological problems associated with assuring ecosystem persistence for future generations, and we hope that the principles will guide certain aspects of ecosystem management. Principles of ecosystem management apply regardless of the degree of past or present human influence on the ecosystem. The basic idea is to view every action or change as an effect in a complex system of processes and to evaluate actions or changes from the perspective of the whole.

Our working assumption is that naturally evolving ecosystems (minimally influenced by humans) were diverse and resilient, and that within the framework of competition, evolutionary pressures, and changing climates, these ecosystems were sustainable in a broad sense. Many present ecosystems modified by modern industrial civilizations do not have all these characteristics. Our guiding premise for sustaining ecosystems and protecting biodiversity now and into the future is to manage ecosystems such that structure, composition, and function of all elements, including their frequency, distribution, and natural extinction, are conserved.[5] Conservation focuses on maintaining and restoring suitable amounts of representative habitats over the landscape and through time.

The following guiding principles expand our premise and provide an ecological basis for analysis and decisionmaking:

(1) humans are an integral part of today's ecosystems and depend on natural ecosystems for survival and welfare; ecosystems must be sustained for the long-term well-being of humans and other forms of life;

(2) in ecosystems, the potential exists for all biotic and abiotic elements to be present with sufficient redundancy at appropriate spatial and temporal scales across the landscape;

(3) across adequately large areas, ecosystem processes (such as disturbance, succession, evolution, natural extinction, recolonization, fluxes of materials, and other stochastic, deterministic, and chaotic events) that characterize the variability found in natural ecosystems should be present and functioning;

(4) human intervention should not impact ecosystem sustainability by destroying or significantly degrading components that affect ecosystem capabilities;

(5) the cumulative effects of human influences, including the production of commodities and services, should maintain resilient ecosystems capable of returning to the natural range of variability if left alone; and

(6) management activities should conserve or restore natural ecosystem disturbance patterns.

These principles involve an evolutionary change in the USDA Forest Service's approach to implementing the Multiple-Use, Sustained-Yield Act on National Forest System lands (Jensen and Everett 1993). Ecosystem management applies to all ecosystems, ranging from those having minimal human influence to those severely impacted by human activity. Ecosystem management should involve consideration of not only goods and services but also the viability of ecological, social, and eco-

[3]Grumbine (1992, pp 184–185) presented four main ecosystem management goals or conservation biology criteria:

1. To protect enough habitat for viable populations of all native species in a given region.
2. To manage at regional scales large enough to accommodate natural disturbances (fire, wind, climate change, etc.).
3. To plan over a period of centuries so that species and ecosystems may continue to evolve.
4. To allow for human use and occupancy at levels that do not result in significant ecological degradation.

[4]For example, Kay (1991) examined a range of characteristics associated with "ecosystem integrity." These characteristics include terms often used to describe aspects of ecosystem dimensions and behavior such as vulnerability, elasticity, inertia, resiliency, stability, constancy, and persistence. Managing ecosystems to achieve all these characteristics of complex natural systems is not only beyond the scope of this paper, it probably also is beyond the scope of our understanding of ecosystem behavior and our capacity to manage.

[5]"Conservative" management means giving the benefit of doubt to the resource rather than to its extraction or development. This principle has been elaborated formally as the "precautionary principle." The principle applies when there is uncertainty about possible cumulative effects, irreversible changes, adverse interaction, or negative long-term effects. For a discussion, see Bella and Overton (1972) and Perrings (1991).

nomic systems now and in the future. Achieving this goal will require that ecosystem conditions, natural processes, natural disturbance patterns, and productive capabilities be incorporated into decisionmaking processes so that human needs are considered in relation to the sustainable capacity of the system. The principles reflect a need to embrace a land ethic that strives above all to sustain biological diversity and productive potentials of ecosystems. Furthermore, the principles may further encourage the distinction between human needs and human wants. High rates of consumption of natural resources stem in part from satisfying human wants and may not be sustainable.

Ecosystem management should maintain all natural ecosystems from alpine tundra to deserts, including their associated riparian and aquatic environments. Scientifically, the most sound basis for ecosystem management is to assure that the variation characterizing ecosystems includes the range of conditions that are expected at various scales in ecosystems uninfluenced by humans. Natural conditions are not static; rather, change is the norm. There is no "balance of nature" (Botkin 1990). Ecosystems are dynamic entities whose basic patterns and processes were and are shaped and sustained on the landscape not only by natural successional processes, but also by natural abiotic disturbances such as fire, drought, and wind. These forces often appear to operate unpredictably both in space and time (frequently resulting in insect and disease outbreaks), thereby maintaining a mosaic of successional stages of forest communities. Collectively, these features influence the range of natural variability of ecosystem structure, composition, and function.

Natural resource management based on our guiding principles would emphasize restoring or maintaining conditions found in constantly changing natural systems. This approach would generally preserve all components of natural ecosystems, but it is not intended to revert all lands to a natural state. It does mean that management activities for ecosystems, regardless of the degree of human impact, must be within the physical and biological capabilities of the land, based upon an understanding of ecosystem function. It means saving all the components of ecosystems, including the structure, composition (including genetic diversity), and processes that characterize natural ecosystems. It means protecting and restoring the pieces of the landscape made uncommon by human activities, carefully reviewing existing impacts of nonnative species, and preventing the introduction of new ones.

Maintaining viable populations of all native animal and plant species is a central theme of ecosystem management, although major scientific knowledge gaps exist. For example, there is limited information identifying what minimum viable populations are. Ecosystem management also conserves soils, aquatic and riparian systems, and water resources. Ecosystem management cannot assure that rare animals and plants will reproduce and thrive, even though the protection of such species is a clear goal in many ecosystems. Ecosystem management is intended to allow normal fluctuations in populations that could have occurred naturally. It should promote biological diversity and provide for habitat complexity and functions necessary for diversity to prosper. It should not be a goal to maintain all present levels of animal populations or to maximize biodiversity.

Tools for maintaining viable species populations are likely to be focused on providing habitats in an appropriate spatial and temporal arrangement. Thus, vegeta-

Vegetation mosaic in the landscape near Martinez Creek, San Juan National Forest, Colorado. Photo by Merrill R. Kaufmann.

tion management continues to be a major tool not only for commodity production, but also for maintaining and restoring biodiversity and for using habitat management to achieve delisting or to avoid listing of threatened and endangered species. However, management of other activities such as recreational use and management of exotic species may also be required (see U.S. Congress Office of Technology Assessment 1993 for an assessment of nonindigenous species). Restoration of severely degraded ecosystems may be impossible, particularly where native species have been extirpated or where soil damage is extensive. In such cases restoration may be partial at best, and it may involve naturalized plants or animals that have been introduced. Clearly ecosystem management requires agreement on overarching principles and extensive cooperation among stakeholders, including landowners and relevant administrative bodies.

Ecosystem management includes the production of goods and services from natural resource systems. However, it is likely to change the amount, types, and ways that goods and services are provided, and undoubtedly will require new approaches to managing human influences. With an emphasis on sustaining ecosystems, resource managers must evaluate activities in the context of sustaining natural ecosystem features. Fire suppression and other activities have changed ecosystems dramatically. Therefore, considerable vegetation management activities, such as prescribed fire, may be desirable to restore the effects of both catastrophic and low-intensity fires and create conditions that favor species relying on past disturbance patterns in the landscape. Tree removal may be desirable to restore stand structure and composition to levels expected from natural disturbances. Where these ecological needs are great, the production of goods and services may occur in the context of reproducing or restoring former patterns of natural disturbances. This may entail restricting certain uses on some lands to assure that ecosystem features are protected or restored, and selecting other lands, if available, that are not important for maintaining the same ecosystem values as places where other societal needs can be met. In the following section, an approach is discussed for using the guiding principles listed above in deciding what actions are needed to conserve ecosystem features.

APPROACH

Analysis Framework

The guiding principles outlined above emphasize the importance of ecosystem integrity in natural resource management. Ecological integrity involves consideration of complex, multidimensional, multiscaled characteristics (Kay 1991). An approach is recommended below as a systematic framework through which ecosystems may be defined and ecological needs can be evaluated and incorporated into the decisionmaking process. Other aspects of ecosystem management, such as integrating humans and ecosystems, are discussed in a later section. There are several methods of classifying ecosystems (Aldrich 1963, Bailey 1980, Bourgeron 1993, Kuchler 1964), and methodology has been presented for designing urban landscapes (McHarg 1971), but only recently are models or methods being addressed for analyzing ecosystem structure and function in relation to current biodiversity issues (Turner and Gardner 1991a; also see a series of articles on ecosystem management in the journal Ecological Applications, August 1992, Vol. 2, No. 3). The hierarchical approach of landscape ecology provides an approach for applying the guiding principles and seems appropriate for most natural resource applications (Jensen and Bourgeron 1993, Turner and Gardner 1991b).

A useful tool in ecosystem management is an ecosystem needs assessment (fig. 2). This assessment provides decisionmakers with information on characteristics that need to be maintained or created to ensure healthy, diverse, and sustainable ecosystems. To manage natural resources effectively, managers need a means to (1) characterize ecosystems at different hierarchical spatial and

Using prescribed fire to reduce fuel as a step toward restoring natural fire disturbance patterns. Photo from Mountainair Ranger District, Cibola National Forest, New Mexico.

Figure 2. — Approach for ecosystems needs assessment using ecological principles at appropriate spatial and temporal scales.

temporal scales, (2) identify patterns and processes important at different scales, and (3) compare these patterns and processes to a set of reference conditions using a coarse- and fine-filter process. This includes selecting an appropriate-sized ecological unit for analysis. The selection of an ecological unit should be made in relation to surrounding landscapes and be based on vegetation, soils, geology, and geomorphology. This frequently will focus on watersheds (see the Forest Ecosystem Management Assessment Team report for a discussion of watershed analysis in ecosystem management and planning) (FEMAT 1993).

A System for Ecosystem Needs Assessment

Hierarchy

Interactions among the biological and physical components of ecosystems and environmental conditions occur at various spatial and temporal scales (Allen and Hoekstra 1992, Allen and Starr 1982). Small ecosystems are found within larger ecosystems, individuals occur within communities, and short-term processes are nested within longer-term processes. Consequently, ecosystem processes and functions must be viewed in the context of a hierarchy of scales in both space and time. Hierarchically organized systems can be divided into discrete functional components operating at different scales of space and time (Simon 1962).

A hierarchical approach provides a framework for analyzing the temporal and spatial characteristics of ecosystems (Norton and Ulanowicz 1992, Turner et al. 1993, Urban et al. 1987) (table 1). When the hierarchical approach is applied to landscape ecology, it provides methods for defining the functional components of a system and defines interrelationships among components at different scales (Urban et al. 1987). A difficulty that must be overcome in ecosystem analysis and management, however, is that it is much easier to grasp spatial scales than temporal scales. We can directly observe ecosystems at one point in time, yet change with time is a fundamental characteristic of natural systems. The temporal aspects of ecosystem behavior must be included in ecosystem management.

A national hierarchical framework of ecological units has been developed and is expected to provide guidance for selection of spatial scales (ECOMAP 1993; see headings in table 1 and fig. 4). This hierarchy is consistent with Forest Service planning levels and many maps and data systems presently in use. The hierarchy also is consistent with those used by the USDI Fish and Wildlife Service, Environmental Protection Agency, and other resource management agencies.

This hierarchy could be used to emphasize ecological aspects of analyses rather than administrative divi-

Table 1. — Analysis scales (ECOMAP 1993) and relationship to a partial listing of features of ecological units. Asterisks (*) indicate spatial scale of applicability for the listed features.

	Ecoregion							
Planning/analysis scale:	**Global**	**Continental**	**Regional**	**Subregion**		**Landscape**	**Land unit**	
Ecological units:	**Domain**	**Division**	**Province**	**Section**	**Sub-section**	**Landtype assoc.**	**Landtype**	**Landtype phase**
Features:								
Air quality	*	*	*	*	*			
Water quality			*	*	*	*	*	*
Weather	*	*	*	*	*			
Hydrology			*	*	*	*	*	*
Aquatic systems			*	*	*	*	*	*
Geomorphic processes				*	*	*		
Fire/fuels regime and risk			*	*	*	*	*	*
Corridors	*	*	*	*				
Travel linkages					*	*	*	*
Species viability		*	*	*	*	*	*	*
Fragmentation	*	*	*	*	*	*		
Habitat relationships		*	*	*	*	*	*	
Insects and pathogens				*	*	*	*	*
Nutrient cycling/longterm soil production				*	*	*	*	*
Succession: community structure/composition:				*	*	*	*	*

sions of ecosystems. Within this hierarchy, several elements of ecosystem function and description are defined that could be used for analysis and decisionmaking (Table 1). The hierarchy of scale and the elements of ecosystems can then be used to analyze the function and sustainability of these ecosystems to compare existing and reference conditions (discussed in the next subsection).

Reference Conditions

Ecosystem complexity is extremely important biologically, but it makes the understanding of ecosystems difficult. Evaluating the status of existing ecosystems requires a standard or set of reference points that characterize sustainable ecosystems. Past conditions may be used as a reference point to predict potential future conditions. Ecosystems developed over geological time under the influence of dynamic climatic conditions, deterministic and stochastic events, and the evolution and adaptation of associated plants and animals, including humans. Ecosystems are complex because they include a number of different elements (plants, animals, soils, etc.).

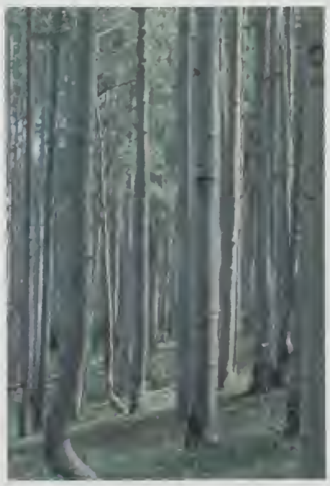
Interactions and dependencies among these elements (ecosystem function) have evolved into a hierarchical arrangement having a range of spatial and temporal scales across which the elements and interactions vary. Natural events characterized by chaos theory at times make ecosystems less resilient and productive and in some cases even unsustainable. Clearly any attempt to manage for volcanic activity or comet collisions with the earth is beyond ecosystem management, and in that sense ecosystem management deals with a subset of all natural variability.

For reference conditions, ideally we would like to have undisturbed ecosystems available for direct evaluation of natural ecosystem structure, composition, and function. In reality, however, most ecosystems have been impacted and modified by modern or aboriginal humans, and few ecosystems are available to study in "pure" form (Swanson et al. 1993). Furthermore, shifts in environmental conditions in recent centuries range from slight (temperature and precipitation patterns) to large (40% higher CO_2 concentration than a century ago). The effects of these shifts are not known, and knowledge of presettlement ecosystem conditions may be incomplete as a point of reference. We can, however, obtain much information from a variety of sources about earlier ecosystems and environmental conditions (table 2). Furthermore, we know or can measure present environmental conditions. Although limited in various ways, models for forest succession, biogeochemical processes, and climate change are increasingly available for assessing ecosystem behavior.

Given that all ecosystems have been impacted directly or indirectly by human activity, as well as by natural phenomena, ecosystems are in transition and will continue to be. Conditions that facilitated the development of ecosystems in the past may or may not be available for or conducive to attaining historic natural conditions in the future. Furthermore, changes in environment, whether natural or anthropic, may cause bifurcations in ecosystem development that completely change the course of ecosystem behavior (Kay 1991). Nonetheless, knowledge of past conditions combined with the best and most current biological knowledge of existing conditions are tools that should be helpful for conserving as many natural features of ecosystems as possible.

Reference conditions characterize the variability associated with biotic communities and native species diversity. They provide insights to important questions such as the natural frequency, intensity, and scale of forest disturbances; the age-class distribution of forest trees; and the abundance or rareness of plant or animal species within an ecosystem (Reynolds et al. 1992). Thus, reference conditions can be used to define target conditions for sustainability or as reference states to estimate how current ecosystems differ from historical ecosystems (Covington and Moore 1992). Depending on their completeness and accuracy, reference conditions also may provide an understanding of the ecological consequences of not returning, or returning only partially, to the natural state.

Unfortunately, the amount and quality of specific information on most historical ecosystems prior to modern disturbance is highly variable. Ecosystem analysis should involve improved methods to characterize the reference conditions that provide an estimate of historical variability (table 2; see also Swanson et al. 1993). Historical variability must be examined cautiously, however — changes in atmospheric conditions since the industrial revolution add uncertainty regarding how historical variability should be used for today's ecosystems. In the interim, the process of historical characterization of ecosystems and landscapes lacking heavy human influence may be a sound approach. This historical review also will aid in regional level analysis by aggregating historic observations to coarser spatial scales. Temporal (successional) variability within landscapes may be characterized through mapping of veg-



Comparison of a pure aspen stand with a stand having ingrowth of conifers. In the Southwestern Region, roughly half of the aspen stands have experienced significant ingrowth during the last 25 years. Photos by Wayne Shepperd.

Table 2. — Examples of analyses and approaches for defining reference conditions.

Analyses and approaches	Information provided	Literature references
Historical records	Past conditions	Hastings and Turner 1965 Dick-Peddie 1993a Emory 1857 US Geological Survey 1899
Tree rings	Climate, disturbance regimes	Baisan and Swetnam 1990 Savage and Swetnam 1990 Swetnam 1990 Swetnam and Betancourt 1990 Swetnam and Lynch 1989, 1993
Palynology	Past vegetation and climates	Foreman et al. 1959 Freeman 1972 Leopold 1951 Martin 1963 Potter and Rowley 1960 Wright et al. 1973
Packrat middens	Past vegetation	Betancourt and Van Devender 1981 Betancourt et al. 1990
Natural areas	Natural variation, minimum human disturbance	Dick-Peddie 1993b Dye and Moir 1977 Jameson and Williams 1962 Muldavin et al. 1990
Archival literature and photographs	Vegetation change in last century	Bartlett 1854 Elson 1993 Gardner 1951 Hastings and Turner 1965 Sallach 1986 US Geologic Survey 1899
Potential and existing natural vegetation	Estimates of future and former vegetation, natural variation	Dick-Peddie 1993c Jameson and Williams 1962 USDA Forest Service 1989
Predictive models	Future vegetation, succession	Bradley et al. 1992
Other literature		Dick-Peddie 1993c Table 2.1

etation types over time to develop an understanding of the dynamics of vegetation. Long-term modeling will be needed to elucidate and refine this approach.

Ideally, historical documents and inventories should provide a significant portion of the data base for understanding reference conditions, including the range of variability. Historical references and reconstructions are generally quite limited, however (Maser 1990). Historical inventories rarely provide all of the information needed to reconstruct an adequate delineation of ecosystems with minimal human impact. This limitation can be lessened by using as many reference sites and sources as can be found and through the use of models. While reference conditions may characterize the status of ecosystems before significant human disturbance, they are not necessarily the desired outcome conditions determined in the ecosystem needs assessment.

Using pre-1870 conditions for reference as "pre-industrial" is often appropriate for many western Forest Service lands. Higher mountain areas in the West have been least impacted by humans. Many of them have been removed from heavy human impact for decades through Wilderness, Research Natural Area, and other protective designations. Some of these areas have been relatively free from postsettlement activities and may be very appropriate for defining reference conditions, though few of them have been studied extensively.

Existing Conditions

There are several sources available for describing existing conditions in an ecosystem needs assessment. In the Southwestern Region (Region 3), site-specific data for existing vegetation are available for many Forest Service lands in the Rocky Mountain Resource Information Systems (RMRIS) (USDA Forest Service 1992b) data base. Potential vegetation may be estimated by using physical characteristics and plant associations (table 3).

Table 3. — The availability of vegetation information in relation to planning and analysis scale.

Planning and analysis scale	Potential vegetation	Existing vegetation
Ecoregion:		
Global	—	—
Continental	Bailey 1980	—
Regional	Bailey 1980	—
Subregion	General Ecosystem Survey Carleton et al. 1991 Bailey et al. 1993	—
Landscape	General Ecosystem Survey Carleton et al. 1991 Bailey et al 1993 Habitat Type	Rocky Mountain Resource Information Systems (RMRIS)
Land unit	Terrestrial Ecosystem Survey (TES) Laing et al. 1986 Edwards et al. 1987 Brewer et al. 1991 Miller et al. 1993 Miller et al. 1994 Habitat Type	RMRIS

In the Southwestern Region, the Terrestrial Ecosystem Survey (TES[6]) Ecosystem Classification System (USDA Forest Service 1985, 1989) identifies potential natural vegetation across landscapes. The TES process uses climate to understand the relationship of soil, vegetation, lithology, and landform by evaluating these components collectively and simultaneously. The entire Southwestern Region is presently mapped using the TES system at the 1:250,000 scale; approximately two-thirds of the Region is mapped at the 1:24,000 scale, and mapping at this scale is expected to be completed by the end of the decade. In the Rocky Mountain Region (Region 2), an Integrated Resource Inventory system is being developed (USDA Forest Service 1993a) along with a District Production Database and an Intra-Agency Common Survey Data Project. It is important that in these data systems disturbance patterns and mixes of various successional stages of natural vegetation are considered at the larger spatial scales and over long periods of time.

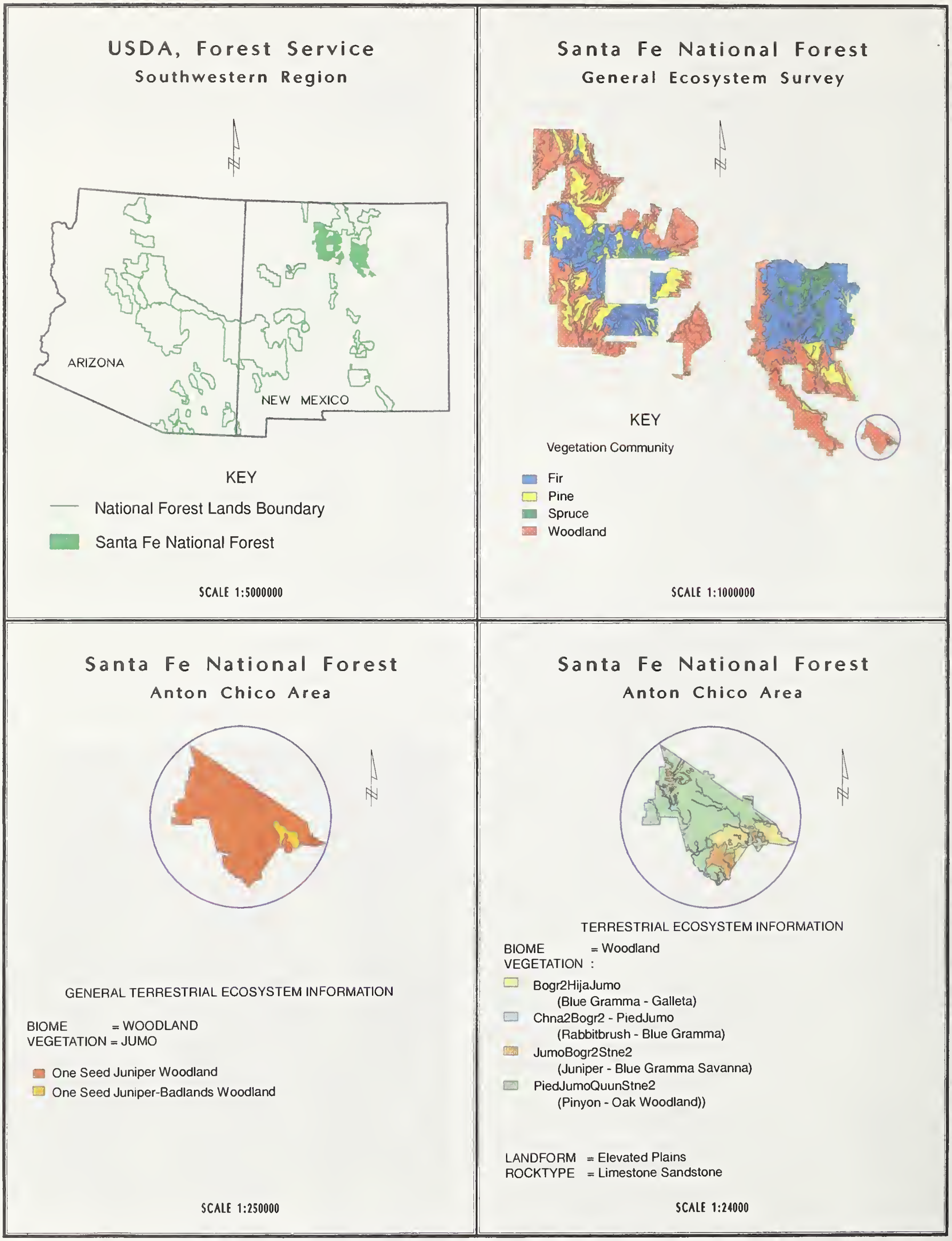
Habitat type (plant association) classification methods developed in the late 1970's and early 1980's estimate potential vegetation at reduced spatial scales. Three habitat type classifications in the Southwestern Region were developed and mapping started in the mid-1980's (Bassett et al. 1987, Larson and Moir 1986, Larson et al. 1987). The classifications include associated plant information, references to TES, a range of productivity, and limited information on implications for vegetation management in each habitat type. These classifications can be used as a basis for developing successional pathways and to develop broader vegetation maps by grouping of habitat types where appropriate. Additionally, other sources of existing vegetation data are available from aerial photographs, LANDSAT imagery, and other remote sensing data. The appropriateness of these and other data bases for evaluating ecosystem conditions needs critical examination (see section on Research Needs).

[6]TES in this document refers only to Terrestrial Ecosystem Survey and not to threatened, endangered, or sensitive species.

Coarse-Filter and Fine-Filter Evaluation

The coarse-filter approach is a strategy for maintaining the components of aggregates by managing for the presence of the aggregates in a given area (Bourgeron and Jensen 1993, Hunter 1990). The concept assumes that a representative array of communities will contain the majority of species and that an array of cover types in an ecoregion will include the appropriate vegetation mosaic. The Nature Conservancy has estimated that 85–90% of the species might be saved by using the coarse-filter approach (Hunter 1990). While the concept has not been thoroughly tested and validated, it has considerable appeal, and it may be possible to apply and test the approach simultaneously (see discussion of adaptive management in a later section on Analysis Responsibilities and Coordination). The advantage of the strategy is that it can operate with relatively little information, if one has enough knowledge to define the larger aggregate meaningfully. In addition, the coarse-filter approach is efficient, and it maintains the integrity of whole ecosystems. A limitation of the coarse-filter approach is that some smaller scale elements will fall outside its purview and require fine-filter strategies. Fine-filters operate at a smaller scale and can be used to identify species, seral stages, or habitat types that

Mexican spotted owl, a threatened species found in the Southwestern Region. Photo by Joe Ganey.



Maps showing general and terrestrial ecosystem information for a portion of the Santa Fe National Forest. Smaller scaled maps incorporate increasingly detailed information. Maps provided by Wayne Robbie.

"slip through" the coarse-filter. Fine-filter analyses require an examination of the smallest-scale elements of concern for the coarse-filter analysis under consideration. They should be limited to a small number of carefully selected elements (Hunter 1990).

A coarse-filter strategy should not be based solely on communities. It should consider both communities and the physical environments that they occupy — in other words an "ecosystem-based" strategy (Hunter 1991). Scale is an important issue. A single ecosystem is typically too small to maintain viable populations of all its species, especially the larger predators. Therefore, the coarse-filter approach is best applied on assemblages of ecosystems (in a hierarchy) that form natural landscape units, such as watersheds and mountain ranges, and connect landscape units with habitat corridors (Hunter 1991; Noss 1983, 1987).

Collectively, the information gathered by examining reference and existing conditions and conducting coarse- and fine-filter analyses can be used with the guiding principles to identify ecological needs at appropriate scales.

INTEGRATING ECOSYSTEMS AND HUMAN NEEDS

Knowledge of ecosystem conditions, natural disturbance patterns and processes, and productive capabilities must be integrated into the decisionmaking process before we can compare human demands with the sustainable capacity of the system. Just as ecological principles aid in determining ecological needs for ecosystems, there also are economic and social principles that aid in defining human needs. Interactions of humans and natural ecosystems can be assessed with a decision analysis model that examines the benefits and costs of alternative courses of action and the risks associated with each action (fig. 3). Various approaches are being developed for assisting the decisionmaking process. An example is the Terrestrial Ecosystem Regional Research and Analysis (TERRA) decision analysis methodology (Woodmansee and Riebsame 1993). Slocombe (1993) outlines additional aspects linking ecosystems and management and provides examples of regional planning and management to accomplish ecosystem management goals. The decision process utilizes National Environmental Policy Act (NEPA) procedures and also other methods for assessing multiple effects of alternatives (Region 3 Integrated Resource Management Process, USDA Forest Service 1993b).

Many past natural resource management decisions have been based primarily on social and economic considerations (Kennedy and Quigley 1993) and frequently have involved relatively independent management schemes to accommodate species or habitat needs (FEMAT 1993). The significant difference brought about by ecosystem management is that ecosystem needs must be addressed to a greater extent than in the past. To accomplish this, the decision analysis model should include an "ecosystem principles filter" by which all courses of action are compared with the ecosystem guiding principles discussed earlier (fig. 3). This filter, not related to the coarse and fine filters discussed earlier, helps determine which economic and social needs can be met while sustaining ecosystems (corresponding to the shaded areas in fig. 1). Those that stay within the guiding principles (i.e., pass through the ecosystem principles filter) will preserve biological integrity and will lead to ecological, economic, and social sustainability. Those failing to pass the ecosystem principles filter may contribute to species loss, degradation of environments, economic instability, social dissatisfaction, litigation, etc.

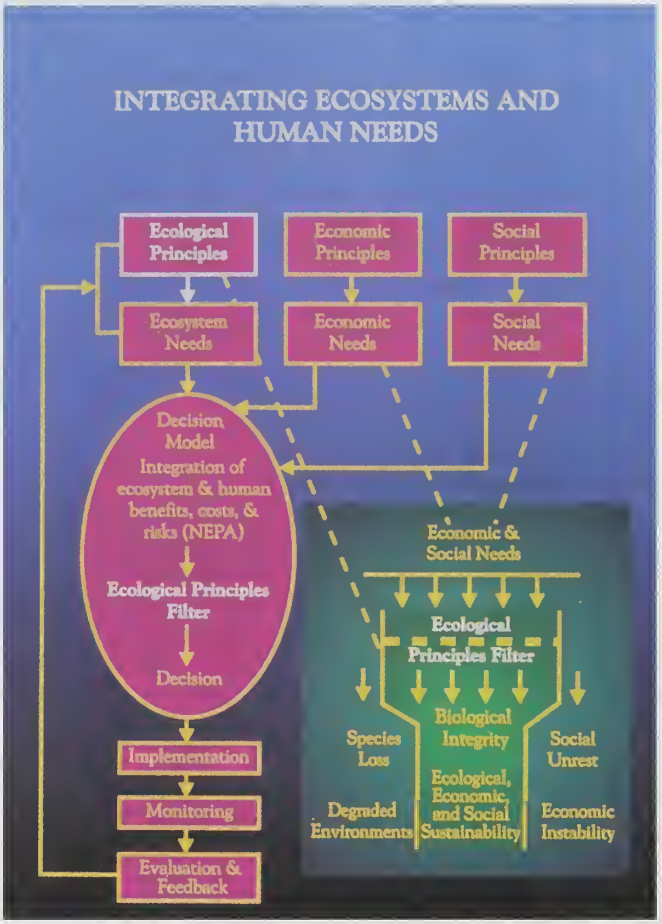


Figure 3. — Integration of ecological, economic, and social needs into a decision analysis model. Economic and social needs are tested against an ecosystem principles filter (illustrated in inset) to determine courses of action having the most desirable outcome for biological integrity and simultaneous ecological, economic, and social sustainability.

ADMINISTERING ECOSYSTEM MANAGEMENT

Analysis Responsibilities and Coordination

Hierarchical analysis is scale-dependent and requires coordination and information flow among agencies and other stakeholders and across administrative levels (see Jensen and Bourgeron 1993 for examples of analysis across planning scales). Various administrative levels within the Forest Service and its partner agencies will

have responsibilities in ecosystem needs assessment. Administrative activities must be structured to address ecosystem needs over large spatial and temporal ranges. Information must flow across the full range of administrative levels (fig. 4), and this information flow must include both data and the results of analyses. In many cases information is limited, and managers must work closely with research scientists to incorporate new information as it becomes available.

Adaptive management procedures are being developed to accommodate changes in knowledge in management activities (FEMAT 1993). Everett et al. (1993) noted the following features of adaptive management: (1) it is based on the concept of management as an experiment, (2) it accepts uncertainties, (3) it requires quantification of objectives, (4) it emphasizes a stated understanding of system operation, and (5) it provides a rapid feedback and evaluation loop for redirection of the experiment. These features are important in keeping ecosystem management aligned with the best knowledge available while coping with information gaps. The treatment of management activities as experiments is critical because it provides an avenue to test unproven concepts believed intuitively to be correct, and it provides focus for monitoring the results of these activities.

Ecosystem boundaries generally do not follow administrative boundaries. Therefore, good ecosystem management should involve all land ownerships. To do this, managers should interact with all administrative units, including federal, state, and local agencies responsible for land or resource management, and private landowners. Furthermore, expertise for ecosystem management may be found not only within the Forest Service (experiment stations and regional and Forest offices), but also in other agencies, universities, natural history museums, nongovernmental organizations, and the private sector.

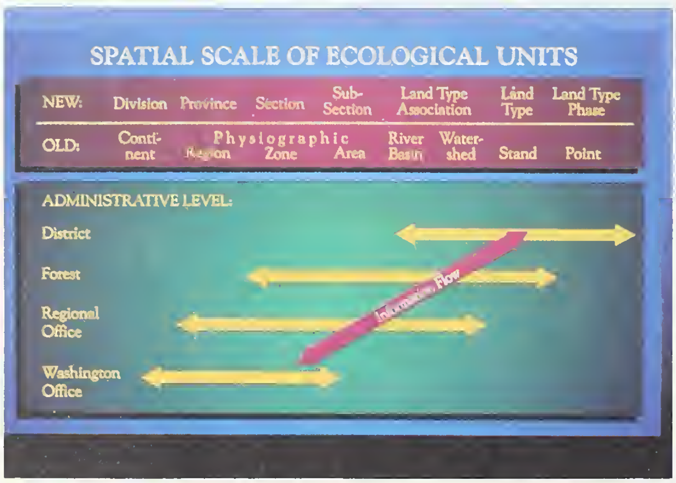


Figure 4. — Relationship of ecosystems needs assessment for various spatial scales of ecological units to Forest Service administrative structure.

Implementation

The following recommendations may be considered in implementing ecosystem management within the Forest Service.

1. As part of the current efforts on re-inventing the Forest Service, review administrative and budgeting structures and staffing to best implement ecosystem management. Present structures may not work effectively for accomplishing ecosystem management objectives.
2. For each application of ecosystem management, follow adaptive management procedures by outlining steps for scientifically evaluating the consequences of the management activities.
3. Integrate ecosystem management into the Land Management Planning process and Forest Plan revisions.
4. Create a Regional Implementation Review Team that meets monthly to review National Forest ecosystem management projects. This team should include scientists as members. This Review Team would assure consistent application of the guiding principles in National Forest management.
5. Encourage the use of ecosystem management principles in all initiatives involving forest management, such as the forest health and pinyon-juniper initiatives.
6. Determine appropriate analysis responsibilities at interregional, regional, forest, and district levels to address temporal and spatial scaling issues. Establish the teams to accomplish the analysis.
7. Coordinate data collection and data management methodology among western regions to assure that data sets for larger spatial scales can be integrated for analyses.
8. Develop effective methods for helping all agencies, publics, and other clients become aware of ecosystem management principles and of the limitations of ecosystems to preserve and/or produce commodities.
9. Use adaptive management in all phases of implementing ecosystem management, from staff involvement to technology transfer.

RESEARCH NEEDS

Coordinated research conducted by various agencies and organizations would address important knowledge gaps in implementing ecosystem management. The following list includes some of the topics requiring research attention.

1. Develop a methodology for determining reference conditions and/or historical conditions.
2. Determine appropriate inventory data bases for present conditions and develop procedures for data analyses for monitoring ecosystem changes. This may include evaluation of the suitability of TES, RMRIS, ECODATA, etc.

3. Develop ecological risk assessment models and data bases for assessing the likely ecological consequences of various management options.
4. Develop and evaluate appropriate ecological process models for forest succession and for natural disturbances that examine the likely consequences of human disturbance on future conditions.
5. Develop validation procedures for models in use or considered for use.
6. Study the ecological implications and consequences of exotic species and of mitigation measures.
7. Study species extirpation, including monitoring techniques, ecological consequences, and mitigation measures.
8. Study the consequences of ecosystem changes on biogeochemical cycles.
9. Formulate regional conservation strategies including land allocations, analysis procedures, and management prescription designs at subregional scales.

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GLOSSARY

Asterisk (*) indicates definition was taken from draft ecosystem management keywords and definitions in the Interim Directive (USDA Forest Service, Washington Office, 1994).

Double asterisk (**) indicates definition was taken or adapted from the glossary in Jensen and Bourgeron (1993). In some cases, definitions were taken from slightly different but related terms.

***Adaptive management:** implementing policy decisions as an ongoing process that requires monitoring the results. It applies scientific principles and methods to improve resource management activities incrementally as the managers and scientists learn from experience and new scientific findings and adapt to social changes and demands.

****Biological diversity (biodiversity):** the variety of life and its processes, including the variety in genes, species, ecosystems, and the ecological processes that connect everything in ecosystems.

****Classification:** the assignment of points, or sample units, to a finite number of discrete types, usually based on an analysis of many variables (e.g., vegetation classification, soil classification).

Coarse-filter analysis: an analysis of aggregates of elements such as cover type or plant community.

Commodity output: the supply of goods or services taken from or supplied by a resource area.

****Conservation:** the careful protection, utilization, and planned management of living organisms and their vital processes to prevent their depletion, exploitation, destruction, or waste.

****Cumulative effect:** the effect on the environment that results from the incremental impact of a proposed action when added to other past, present, and reasonably foreseeable future actions.

****Decision analysis model:** an organized system that policymakers and managers can use to select a course of action, often but not necessarily a formal model.

***Disturbance:** a discrete event, either natural or human induced, that causes a change in the existing condition of an ecological system.

Disturbance pattern: arrangement of disturbances over space and time.

***Ecological approach:** natural resource planning and management activities that assure consideration of the relationship among all organisms (including humans) and their environment.

***Ecological classification:** a multifactor approach to categorizing and delineating, at different levels of resolution, areas of land and water having similar characteristic combinations of the physical environment (such as climate, geomorphic processes, geology, soil, and hydrologic function), biological communities (such as plants, animals, microorganisms, and potential natural communities), and the human dimension (such as social, economic, cultural, and infrastructure).

Ecological principles: the biological basis for sound ecosystem management through which ecosystem sustainability is ensured.

***Ecological process:** the actions or events that link organisms (including humans) and their environment such as disturbance, successional development, nutrient cycling, carbon sequestration, productivity, and decay.

Ecological unit: an assessment area based on vegetation, soils, geology, and geomorphology.

***Ecoregion:** a continuous geographic area over which the macroclimate is sufficiently uniform to permit development of similar ecosystems on sites with similar properties. Ecoregions contain multiple landscapes with different spatial patterns of ecosystems.

***Ecosystem:** living organisms interacting with each other and with their physical environment, usually described as an area for which it is meaningful to address these interrelationships.

Ecosystem composition: the constituent elements of an ecosystem.

Ecosystem function: the processes through which the constituent living and nonliving elements of ecosystems change and interact, including biogeochemical processes and succession.

***Ecosystem management:** the use of an ecological approach that blends social, physical, economic, and biological needs and values to assure productive, healthy ecosystems.

Ecosystem need: an action required to ensure that an ecosystem is sustainable.

Ecosystem restoration: returning an ecosystem from a nonsustainable to a sustainable condition.

Ecosystem structure: the spatial arrangement of the living and nonliving elements of an ecosystem.

****Ecosystem sustainability:** the ability to sustain diversity, productivity, resilience to stress, health, renew-

ability, and/or yields of desired values, resource uses, products, or services from an ecosystem while maintaining the integrity of the ecosystem over time.

Element: an identifiable component, process, or condition of an ecosystem.

Exotic species: see Nonnative species.

Fine-filter analysis: an analysis of components of aggregates such as plant communities in a cover type or species in a plant community.

Genetic diversity: the genetic variation within and among individuals in a species.

Habitat type: plant association based on a climax overstory species and an indicator understory species.

*__Healthy ecosystem:__ an ecosystem in which structure and functions allow the maintenance of the desired condition of biological diversity, biotic integrity, and ecological processes over time.

Hierarchical approach: an analysis approach accounting for differences in space and time.

**__Hierarchy:__ a sequence of sets composed of smaller subsets.

Historical ecosystem: an ecosystem at a specified previous time.

**__Historical variation:__ range of the spatial, structural, compositional, and temporal characteristics of ecosystem elements during a period specified to represent "natural" conditions.

*__Human dimension:__ an integral component of ecosystem management that recognizes people are part of ecosystems, that people's pursuits of past, present, and future desires, needs, and values (including perceptions, beliefs, attitudes, and behaviors) have and will continue to influence ecosystems and that ecosystem management must include consideration of the physical, emotional, mental, spiritual, social, cultural, and economic well-being of people and communities.

Human impact or influence: a disturbance or change in ecosystem composition, structure, or function caused by humans.

*__Landscape__: an area composed of interacting ecosystems that are repeated because of geology, land form, soils, climate, biota, and human influences throughout the area. Landscapes are generally of a size, shape and pattern which is determined by interacting ecosystems.

Natural disturbance: periodic impact of natural events such as fire, severe drought, insect or disease attack, or wind.

Natural ecosystem: an ecosystem that is minimally influenced by humans and that is, in the larger sense, diverse, resilient, and sustainable.

**__Natural variation:__ see Range of variability.

Nonnative species: a species introduced into an ecosystem through human activities.

**__Plant association:__ a kind of plant community represented by stands occurring in places where environments are so closely similar that there is a high degree of floristic uniformity in all layers.

**__Potential vegetation:__ vegetation that would develop if all successional sequences were completed under present site conditions (e.g., habitat type).

*__Productive:__ the ability of an area to provide goods and services and to sustain ecological values.

*__Range of variability:__ the spectrum of conditions possible in ecosystem composition, structure, and function considering both temporal and spatial factors.

Reference conditions: conditions characterizing ecosystem composition, structure, and function and their variability.

*__Resilience:__ the ability of an ecosystem to maintain the desired condition of diversity, integrity, and ecological processes following disturbance.

*__Restoration:__ actions taken to modify an ecosystem in whole or in part to achieve a desired condition.

*__Scale:__ the degree of resolution at which ecological processes, structures, and changes across space and time are observed and measured.

Southwest: the states of Arizona and New Mexico.

Spatial scale: the level of resolution in space perceived or considered.

*__Stewardship:__ caring for land and associated resources and passing healthy ecosystems to future generations.

**__Succession:__ a directional composition change in an ecosystem as the available organisms modify and respond to changes in the environment.

*__Sustainability:__ the ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time.

Temporal scale: the level of resolution in time perceived or considered.

Undisturbed ecosystem: an ecosystem that has not been influenced by human activity.

*__Watershed:__ an area of land with a characteristic drainage network that contributes surface or ground water to the flow at that point; a drainage basin or a major subdivision of a drainage basin.

APPENDIX 1

Members of the Southwestern Regional Ecosystem Management Study Team

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APPENDIX 2

Charter of the Southwestern Regional Ecosystem Management Study Team

Former Chief F. Dale Robertson of the USDA Forest Service directed on June 4, 1992, that regional foresters submit strategies for implementing ecosystem management. The Southwestern Regional Forester, Larry Henson, and the Rocky Mountain Station Director, Denver Burns, established the Southwestern Regional Ecosystem Management Study Team in December 1992 to describe an ecological basis for implementing ecosystem management. Regional Forester Henson also established an Ecosystem Management Interdisciplinary Team to coordinate ecosystem management in the Southwestern Region. The Interdisciplinary Team may use this report when preparing its recommendations for the regional forester. When the work of the Social and Economic Study Team is completed, the Ecosystem Management Study Team may review its own work to determine if any revisions or changes are required.

The Team's charter has three parts:

1. Evaluate existing approaches to ecosystem management used in other areas of the United States and world for their applicability to sustain ecosystems in the southwestern United States.
2. Describe the principles and rationale used for developing ecosystem management recommendations that will sustain healthy southwestern ecosystems.
3. List assumptions, further research needs, management recommendations, and the implications of applying the recommendations.

Following this charter, our procedure was to evaluate existing ecosystem management approaches and to discuss our collective knowledge, invite expert speakers to discuss their knowledge, review the literature, and finally discuss concepts as a group. We met for one-week periods during December 1992, January 1993, February 1993, March 1993, April 1993, August 1993, September 1993, and December 1993.

Invited speakers and their topics included R. G. Bailey (biotic provinces), Patrick Bourgeron (overview of ecological thinking in industrial countries), Ann Hooker (Forest Service Washington Office ecosystem management efforts), Mark Jensen (ecosystem efforts in the Forest Service Regions 1 and 6), Esteban Muldavin (GIS approach for classifying vegetative communities), and Roger Soles (UNESCO Man and Biosphere program). The literature we considered is partially referenced in the Literature Cited section of this report. Discussions on a wide range of topics dealing with ecosystem management led to the development of our "Guiding Principles." We developed the content of this report in a group setting.

APPENDIX 3

Sampling of Reviewers' Comments on the September 1993 Draft

The following comments were selected from reviewers' correspondence to illustrate the reactions to a draft of this document circulated in November 1993. The primary difference between the reviewed and final draft is that the earlier draft provided less detail about the human dimension. The comments included a number of valuable observations and are provided here to help the reader obtain a sense of the range of issues held to be important in addressing ecosystem management and the acceptability of this document.

"In general, the Department supports the concepts presented in the document. If implemented, we believe this document can provide guidance toward achieving sustainable natural systems and an even flow of products and services from National Forest lands. The Department recognizes that consideration of social and economic factors is a political reality. However, we hope that the scientific team's input will not be further diluted by incorporating socio-economic factors within its report. In our opinion, these considerations are necessary but should not be part of the scientific team's discussion."— Duane L. Shroufe, Director, Arizona Game and Fish Department, Phoenix, AZ.

"The draft document provides general guidance for development of ecosystem management on National Forest lands. It is disappointing that it does not go further in helping the manager to decide how to implement ecosystem management, although this seems to have been beyond the team's charter. The recommendations for administering ecosystem management call for cooperation with all land managers in a given ecosystem. This should tie in well with the Fish and Wildlife Service's Partners for Natural Resource Conservation Strategy. ...

"The concepts are inarguably the state-of-the-art thinking for ecosystem management and we support the premise of the document, particularly concerning the value of managing to ensure the viability of ecosystems now and into the future.

"We support the efforts to implement a management strategy that has as its first priority the stability and diversity of ecosystems as functional units. However, additional work needs to be done to bring the concepts developed in this document to fruition as an implementation plan." — John Rogers, Regional Director, USDI Fish and Wildlife Service, Albuquerque, NM.

"This draft report represents a good first step in implementing ecosystem management 'on the ground.' The report deals in generalities, which is probably appropriate at this stage. It recognizes that significant deterioration has occurred in many ecosystems and that past natural resource management decisions have been based primarily on social and economic considerations. It also recognizes that ecosystem needs must be addressed over large spatial and temporal ranges, and that information flow must occur across the full range of administrative levels. These are important concepts, and the Department commends the study team for these insights." — Bill Montoya, Director, New Mexico Department of Game and Fish, Santa Fe, NM.

"Overall, I found the manuscript to be well-written and a nice general discussion of what ecosystem management entails as I see it. In fact, I think that it would be acceptable for publication in Ecological Applications. Your team has put a lot of thought into this topic that should be shared through the journal literature as well as a station report. ...

"It may not be possible to assure sustainability 'while meeting social and economic needs.' ... Here readers will get the impression that ecosystem management can be everything to everyone. I suspect that ecosystem management often will not mean drastic socio-economic changes, but that will not always be the case.

"I liked your section on guiding principles. It's true that there is a lot we don't know about whether or not our current managed ecosystems continue to be resilient, diverse, self-sustaining, and productive, but I think that we know enough to adopt the guidelines that you identify. Critics of this report may not be happy with some of them, but I think they are defensible." — Dennis H. Knight, Department of Botany, University of Wyoming, Laramie, WY.

"This paper presents a conceptual framework for ecosystem management based on up to date ecological principles such as hierarchical structure, sustainability and landscape ecology. Although the authors present a progressive framework for management and the reviewer agrees that such a framework is appropriate, the document may not be specific enough to guide the implementation of the principles or, perhaps more importantly, state the principles in ways that can be evaluated. ...

"Humans have managed to perpetuate, for millennia, economic and ecological systems involving various levels of interaction between humans and 'nature'. Tim Allen said recently that the spatial patterns of farms in ancient times were the emergent properties of human-ecosystems designed to be 'sustainable' given certain constraints. Systems theorists believe that humans are simply maximizing entropy creation by dissipating energy most efficiently. This idea is difficult to escape . . . and suggests that even the process the Forest Service is going through with the creation of this document and others like it will lead to new system configurations that will prevent the system from collapsing (as we believe it would if we simply removed all the timber) so that it may continue to dissipate energy into the future.

"Unfortunately, the idea of sustainability and the idea that the human system is continually reorganizing to maximize energy flow are difficult to test and difficult to falsify. It seems that before goals to achieve sustainability and hierarchical ecosystem structure are implemented it would be worthwhile specifying how to test the ideas so that sustainable systems can be de-

tected if they should happen to be created by management." — Bruce T. Milne, Department of Biology, University of New Mexico, Albuquerque, NM.

"I want to applaud your team for moving quickly to address a very complex issue — that of determining what 'ecosystem management' is, and, what is more important, how you as an agency will attempt to implement the plan. At this point, for the most part, discussions of ecosystem management have been a lot like discussions of the weather — everybody talks about it, but nobody is doing anything about it. The concept of ecosystem management is relatively easy to understand, and it is certainly how we should approach forest resource management. However, the implementation of ecosystem management will be the most complex thing we have ever attempted to do.

"Your team has a very difficult task. I believe you have done a very commendable job of introducing the concept of ecosystem management and then discussing the general approach that will be used to integrate ecosystem management concepts into the management of National Forest and Rangelands of the Southwest." — David Wm. Smith, College of Forestry and Wildlife Resources, Virginia Polytechnic Institute, Blacksburg, VA.

"Overall, I believe that you have the makings of an excellent paper, one that will not only serve your agency, but others as well, in helping to reorient thinking and establish new approaches to ecosystem management. The paper very clearly addresses many of the concepts that I and, I believe, others have been thinking of. ...

"Fundamentally, I believe that ecosystem management is just as much a social challenge as it is a scientific challenge, perhaps even more so. The complexities on the social side are far too broad for me to attempt to address here. But, basically, they might be characterized as a maze of values, attitudes, and customs represented by a host of competing institutions coming to bear against each other through planning, judicial, and political processes. In short, there must be a better way of doing business. I believe that ecosystem management may provide such an opportunity if characterized and approached properly. In this context, I don't believe that our current planning processes are entirely suitable vehicles for doing so.

"What is needed are new ways of engaging publics and science through a process of evaluating social, economic, and environmental objectives, achieving common goals and objectives based upon sustaining ecological and other landscape functions (such as watershed and hydrology), and pursuing those objectives through adaptive management.

"Thank you for the opportunity to review the document. It is certainly one of the best that I have read on the subject, and one that will be most useful once completed." — Gary McVicker, USDI Bureau of Land Management, Lakewood, CO.

"Not only are humans dependent upon functioning ecosystems, but in many or most cases they are the dominant stress to ecosystems. By that I mean we generally impose chronic stress on ecosystems against which there have evolved few protective mechanisms. Economic philosophy leads directly to much of this stress, and economics and ecology can not be separated especially on issues as sustainability. ...

"Many, perhaps most, scientists believe virtually all ecosystems are now under anthropic stress. Atmospheric contaminant inputs occur globally to varying degrees. This is the most extensive chronic stress imposed on ecosystems. Since ecosystems have not evolved defensive mechanisms for chronic stress, it is likely most, if not all, are under varying degrees of alteration due to anthropic derived stress. I personally doubt ecosystem restoration, beyond the 'kinder, gentler silviculture', etc., is feasible particularly for any lands not suitable for intensive management. The only solution in this instance is mitigation of the anthropic derived stress, i.e., air pollution, water pollution, incompatible conterminous land use. ...

"With global population soaring and individual standard of living declining, we do not have time to develop a full understanding of ecosystem structure and function before taking steps to mitigate anthropic-derived stress. For many ecosystems in the west, I think we are quickly approaching the point where we can make good educated guesses as to the effect of present stress on ecosystem function and structure, and even biodiversity.

"Interesting document and a good first step. I hope all realize that this is a long-term effort, not a flash in the pan as are most national initiatives." — Robert Stottlemyer, USDI National Biological Survey, Fort Collins, CO.

"The report does a proficient job of achieving its goal of providing an ecological basis for ecosystem management. It is truly a formidable task. My primary concern is that 'business as usual' may still occur, but under the guise of an ecologically based approach. Because of the broad nature of this topic there is considerable room for interpretation of this document. Factions that are politically or strictly economically motivated could easily exploit that 'wiggle room'. ... In general, I recommend more precise operational definitions of some terms, and clarification of the approach to be taken when there is conflict between economics and ecology. . . .

"Human needs are very different from human wants. Many economic arguments for continued harvesting have been based on 'wants' rather than needs. A sentence or two could be added to make this distinction, perhaps acknowledging that the US is leading the world in rates of consumption of natural resources. Those rates do not always reflect 'need' and may not be sustainable." — Susan K. Skagen, USDI National Biological Survey, Fort Collins, CO.

"Ecosystems don't evolve. They assemble or disassemble as species are added or disappear. Managing ecosystems so that all elements are conserved is impossible, or at least counterproductive; ecosystems are dynamic by their nature. Ecosystems should be managed so that they preserve their functional integrity and so

that the species within them retain their evolutionary potential. ...

"It is very true that ecosystem management cannot ensure that rare animals will persist. However, the 'coarse filter' approach is a cop-out that does not follow the guidelines in the NFMA to manage for viable populations of all vertebrates. I would guess that about 5% of the species in a given management unit are vertebrates — are these the ones you will allow to go extinct? This is my major quarrel with 'ecosystem management'. A better approach is 'biodiversity management' that includes ecosystem management plus pays attention to species management and genetic management as well." — Peter Brussard, Biodiversity Research Center, University of Nevada, Reno, NV.

"The limited time for review precluded me from sharing the document with other members of the American Ornithologists' Union. Therefore you should regard the comments as mine, rather than as being representative of the organization.

"Overall the document lays out the basis for ecosystem management and provides a reasonable approach to implement it. There are a few aspects that cause me concern however.

"1) I agree with the premise that natural ecosystems have the characteristics that one should be managing for — in particular, resiliency and persistence. However, you ignore the history of thousands of years of human habitation of North America that has clearly shaped the landscape. Although Native Americans did not practice large scale logging and thus had fairly minimal direct impact on forest ecosystems, they had particular and often acute impacts on open environments. In addition, the impacts of fire and of hunting may have also affected forested ecosystems. I'm not sure how you can deal with this in your paper and in your management, but it at least needs to be recognized.

"2) One implication of the historical impact of humans is to think of ecosystem management not as trying to restore 'natural conditions', but rather to manage prospectively for self-sustaining ecosystems whose composition is based on the physical characteristics of the landscape. In other words, the goal should not be to recreate, but rather to create a situation where ecological and evolutionary processes will lead to plant and animal conditions that are stable for that particular site at that particular time." — David Blockstein, The American Ornithologists' Union, Washington, DC.

"I find the document to be very exciting and almost revolutionary in its implications. This is the sort of thinking that all of us have been trying to urge upon society for the past two decades, once we recognized that the Endangered Species Act and Smokey Bear gimmicks were not going to save the world as we wanted it. I congratulate you and your colleagues, several of whom are well known to me, for your good work on this project, and I hope that the document emerges from the review process relatively unscathed.

"I particularly like the so-called 'Guiding Principles,' since there is a clear recognition that 'nature thrives on perturbation.' . . . We should be in the business of preserving the integrity of natural processes in order to save what we categorize as ecosystems. ...

"We cannot go back in ecological time, . . . and we must play the hand that the smokestack society era dealt us. It is my conviction that if we emphasize the restoration of natural processes, rather than dwelling on the particular species-level components of ever-dynamic ecosystems, we will probably do more good in the long run. This is the main reason I like your document." — Lloyd Kiff, Director, Western Foundation of Vertebrate Zoology, Camarillo, CA.

"The Region's guiding principles are based on the wrong premise — that 'natural' ecosystems evolved with minimal or no influence from humans. In fact, Native Americans had a profound influence on the forest and rangelands through the use of fire. ...

"The American Forest & Paper Association has adopted six key principles for ecosystem management that address the more practical needs of federal land managers in defining ecosystem management goals. These include (in abridged form): (1) humans are parts of ecosystems; (2) healthy ecosystems are essential to the health and sustainability of human societies and the quality of human life; (3) ecosystems are dynamic, resilient and subject to disturbances; (4) active resource management is an important (often essential) component of ecosystem management; (5) ecosystems are adaptable to change, and identifying the 'best' management option is both a social and biological issue; and (6) management outcomes cannot be predicted with complete precision, but adaptive management will help to limit risk.

"The Southwest Regional Ecosystem Management Study Team should consider AFPA's principles as a more suitable approach for providing 'an ecological basis for analysis and decision-making.' By contrast, the principles and assumptions developed by the team indicate that the team misunderstood the Chief's June 1992 direction on ecosystem management. Unlike the Chief's direction, the team has established a set of principles based on non-human intervention in the ecosystem." — Anonymous review from the American Forest & Paper Association, forwarded to the Study Team by Donald K. Olson, President, Kaibab Forest Products Company, Phoenix, AZ.

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Guiding principles based on conservation biology are applied in assessing ecosystem needs. Ecosystem, economic, and social needs are integrated in a decision model in which the guiding principles are used as a primary filter for evaluating proposed actions. Management practices consistent with the guiding principles are likely to lead to ecological, economic, and social well-being, while those practices that are not consistent with the guiding principles risk species loss, degraded environments, and long-term social problems.

Keywords: Ecosystem management concepts, guiding principles, conservation biology, ecosystem needs, human dimension, hierarchy, reference conditions, coarse-filter and fine-filter analyses, decision model.

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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Fort Collins, Colorado*
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Rapid City, South Dakota

*Station Headquarters: 240 W. Prospect Rd., Fort Collins, CO 80526